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FURTHER EVIDENCE FOR HIBERNATION OF BEARS

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by

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Introduction.

In the previous symposia on the Biology of Bears, we presented the argument that three species of bears undergo a form of dormancy which is in several senses more profound than in the typical or classical hibernators, such as woodchucks (*Marmota monax*)(Folk *et al*. 1967, 1968, 1972, 1977). In essence, frequently these three species of bears (grizzly, black, polar) are independent of food and water, and do not defecate or urinate for three to five months, and probably as long as seven months in northern Alaska. These observations have been confirmed by Nelson *et al*. (1973) and Craighead, J.J. *et al*. (1974). Bears do not drop their body temperature in hibernation to the same extent as observed in small hibernators, such as woodchucks. This would be a biological disadvantage to bears because it would take them several days to warm up spontaneously at a time of emergency. However, Craighead *et al*. (1974) has shown a drop from the usual core temperature of 37°C to 31.8°C; Rausch (1961) found a drop to 33.0°C. There is other physiological depression, however: all three species of bears slowly alter their cardiovascular function over a period of approximately one month in the fall; their summer sleeping heart rate ranges from 40 to 50 bpm; yet in the state of dormancy in extreme winter weather, they frequently have a heart beat as low as 8 to 10 bpm. These results have been detailed in the preceding four references from our Laboratory.

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During winter dormancy some bears have been observed to take on the dormancy position of small hibernators: specifically the body is rolled into a tight ball with nose near tail and forehead pressed against the ground. We frequently observed one black bear in this position, when he was maintained at air temperature of -1°C for an entire winter. He sometimes raised his head but was not observed to leave his nest in the corner of the cage all winter. We have attempted to record his position in a drawing (Fig. 1). It is important that other observers record such information; possibly the inactivity of our bear was exceptional. If it is the rule, then we must ask why muscles do not become cramped, or bones show degenerative osteoporosis.

In one biochemical characteristic, the black bear at least is like other hibernators. In hibernation there is very high serum magnesium in typical hibernators such as the 13-lined ground squirrel, the woodchuck, and the bat. The black bear in dormancy also has this same high serum magnesium but it is not found in non-hibernator mammals when they sleep or under any circumstances in health.

In the present paper we would like to consider the EKG of the same three species of bears using it in part as a taxonomic characteristic. Each heart beat is electrically composed of three spikes referred to as the "P", the "R", and "T" waves. It has long been established that hibernators (such as woodchucks) have a very short interval between the second spike (R wave) and the third spike (T wave)(Dawe and Morrison, 1955). The T wave represents the relaxation of the heart and the preceding two waves (P and R) represent contraction. Therefore we say that the relaxation interval of hibernators is relatively fast. It is the purpose of this paper to examine the relaxation interval of bears and to determine whether it is more like non-hibernators or hibernators. There will be no attempt to explain the meaning of the short relaxation interval of hibernators but we would like to use it as a "taxonomic clue" to common physiological characteristics.

Methods.

Three species of bears were given winter dens in the extraordinarily cold environments of Point Barrow or Fairbanks, Alaska. Some of the dens were maintained at the Naval Arctic Research Laboratory and others were maintained at the River Laboratory of the Arctic Aeromedical Laboratory. Small physiological radio-capsules were implanted in the abdominal cavities of these bears by methods described in earlier papers (Folk 1964, Shook and Folk 1965, Folk and Copping 1973). In the same publications, the method of recording has been described; specifically, recording paper was turned on for one-half minute every half hour for periods sometimes lasting for two months. Signals from the radio-capsules were recorded by heat stylus. A roll of paper usually lasted three days. On some occasions the record which was made was unsatisfactory due to electrical noise from the atmosphere or the ground. On most occasions at least heart-rates could be easily read. On about 25% of the records, the complete EKG or at least the R and the T wave could be read. In the present paper we analyze the results from these EKG records. As stated above, the short interval between the R and the T waves is characteristic of the hibernator. This interval is referred to as the "QT interval"; it could also be referred to as the "relaxation interval" although this is an oversimplification because a small part of the contraction of the ventricle is actually included within this interval. Using the same radio capsules and the same technique as with the bears, one woodchuck and six marmots (Marmota caligata) were studied. Because these are in the same genus, we will refer to them collectively as "marmota-species." The woodchuck was in a natural burrow (Folk 1976). The comparison between non-hibernators and hibernators could best be made with human subjects since many thousands of measurements of QT intervals have been made on human subjects and the values are to be found in numerous citations concerned with the EKG. A standardized procedure was used for measuring each interval: ten QT intervals were always measured. If there were only ten heart beats per minute, all QT intervals were measured. If there were 20 heart bpm, every other heart beat was used; if the heart beat was rapid with a rate such as 100 bpm, only the first half of the record was used (50 beats) and the middle 20 beats were selected and every other beat was measured. There is an effect of breathing upon heart rate but we believe that this effect was randomly distributed through our sample by the standardized procedure used.

Our comparisons between animals were made with absolute values of the QT interval usually at the same heart rate, or at the comparable sleeping heart rate of the species. It was tempting to describe a ratio between the QT interval and the total interval between heart beats. This proved unsatisfactory because the QT interval is relatively constant and only varies systematically and slightly with a change of heart rate, but the total interval between heart beats is extremely variable partly due to respiration.

Satisfactory records were obtained from one polar bear in summer and winter, one black bear in summer and winter, one black bear in winter, and two grizzly bears in summer and winter.

Results.

A comparison of the relaxation intervals of non-hibernators and hibernators requires the following questions. Is there a difference in relaxation interval: 1) between man, bears, and marmota-species during summer sleep; 2) between these species, during activity in summer; 3) within each species, comparing summer sleep and summer activity; 4) within species comparing summer sleep and winter sleep; 5) within species comparing summer and winter active heart rates; 6) within species comparing winter sleep and hibernation.

These same questions are expressed in tabular form as:

	Summer Sleep	Summer Active	Winter Sleep	Winter Active	Hibernation
Man	A	D	--	--	--
Bears	B	E	H	J	L
Marmota Types	C	F	I	K	M

We compare: 1) A, B, and C (Table 1);

2) D, E, and F (Table 2);

3) A with D, B-E, C-F (Table 2);

4) B with H, C-I (Table 3);

5) E with J, F-K (Table 4);

6) H with L, I-M (Table 1).

Using round figures the relaxation interval in summer sleep of man is about 0.4 sec, that of the grizzly bear about 0.2 sec, the polar bear 0.1 sec, the woodchuck 0.1 sec, and the marmot 0.1 sec (Table 1). Evidently the EKG pattern of bears and the marmot-type of hibernator is similar under these circumstances. This similarity still holds during activity in summer (Table 2). Next we consider the question of winter activity; much of the time in winter, both bears and marmota-species are alert and normothermic, between bouts of hibernation. When these animals are not in dormancy, does the relaxation interval compare (within species) in winter and summer (Table 3). The answer is that it is larger in winter at the same sleeping (not hibernating) heart rate. This prompted us to do an analysis between summer and winter with active heart rates of bears and marmota-species (Table 4). There was approximately a 43% increase of the relaxation interval at a high heart rate of winter over summer. This increase is especially evident in a graphic analysis (Fig.); the graph of summer heart rates is significantly different for both woodchuck and arctic marmot. The results for bears is not quite as striking (Fig. 4); for grizzly bear No. I the relaxation intervals were very different at low and high heart rates. For grizzly bear No. II, in one of the two cases, the relaxation interval was different. There was inadequate information for the black bears to make this point.

Putting aside the effect of summer and winter, the slope in both figures also demonstrates that the relaxation interval shortens with higher heart rates, a point made earlier in Table 2. This point is best realized without considering hibernation, since one would expect that in hibernation which implies a very cold heart, the relaxation interval would be slower (Table 1). The graphs are best interpreted for the marmota-species by considering just heart beats higher than 25 bpm (non-hibernating) and for bears above 40 bpm. For example, there was a 9% drop in the relaxation interval for the marmot when, in the summer, its heart rate increased from 92 bpm to 152 bpm (see also Table 3).

Discussion.

The intention of this paper was to use the relaxation interval as a taxonomic clue to a common physiological characteristic, to determine whether the behavior of the hearts of bears (when they were not in the winter den) were more like that of man or like the so-called usual or classic hibernators. During summer sleep, the relaxation interval of bears (0.18) was about one-half of that of man (.39), and approximately the same as that of the marmota-species (.11). Thus this aspect of the physiology of bears does match with the more common types of hibernators. As an example of serendipity, there were additional results from this study; for both the bears and the marmota-species, it was evident that the heart behaves very differently in winter even when the animal is not in hibernation. There is a conspicuous shortening of the relaxation interval in summer or a lengthening in winter. Another phenomenon is that, with all species, the relaxation intervals shortens with increased activity (higher heart rate); the behavior of the winter heart with its prolonged relaxation interval is consistent even as the intervals change with increased heart rate. This last observation is new for bears and marmota-species; namely there is approximately a 45% change in the relaxation interval as these animals become more active and have an increased heart rate. Although it is not the purpose of this paper to analyze the behavior of the heart in hibernation, it should be pointed out that, as might be expected, the relaxation interval is prolonged in the cold heart during the hibernation process.

To summarize, in an earlier paper, we suggest that bears could be considered better hibernators than the classic, usual small hibernators because only the bears are independent of food, water, defecation, and urination for many months. Now the "taxonomic" evidence of the present paper places bears close to other hibernators using cardiac function as a criterion. It is our conclusion that we need no longer stumble over such terms as "winter denning", "winter dormancy", "winter sleep", or "winter lethargy". After the ten years of experience with bears in winter dens, in not only our laboratory but also in the laboratory of Ralph Nelson at the Mayo Clinic, both groups of investigators have agreed that bears assume a physiological state in winter which might best be designated as "hibernation".

Acknowledgment.

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TABLE 1

THE QT INTERVAL (SECs ± SE)

(BY IMPLANTED RADIO-CAPSULE)

		SUMMER SLEEP		WINTER HIBERNATION	
		QT	HR	QT	HR
MAN		**0.39**	**60**		
GRIZZLY BEAR	1	0.280 ±.013	44	0.580 ±.027	12
	2	0.172 ±.010	48	0.367 ±.002	26
MEAN		**0.226 ±.057**	**46±2**	**0.474 ±.111**	**19±7**
BLACK BEAR	1			0.421 ±.018	18
	2			0.476 ±.016	26
MEAN				**0.448 ±.033**	**22±4**
POLAR BEAR		**0.141 ±.003**	48		
WOODCHUCK		0.035 ±.005	92	0.155 ±.005	10
MARMOT	1	0.121 ±.003	96		
	2	0.090 ±.007	96	0.170 ±.015	12
	3	0.151 ±.012	96		
	4	0.157 ±.005	82		
	5	0.174 ±.007	96		
	6	0.170 ±.008	90		
MEAN		**0.144 ±.031**	**90±8**	**0.170 ±.015**	**12**

TABLE 2

QT INTERVALS FOR SUMMER SLEEPING AND ACTIVE HEART RATES

		SLEEP		ACTIVE	
		QT	HR	QT	HR
MAN		0.39	60	0.33	90
GRIZZLY BEAR	1	0.280 ±.013	44	0.238 ±.006	90
	2	0.172 ±.010	48	0.169 ±.011	90
	MEAN	0.226 ±.057	46±2	0.204 ±.036	90
BLACK BEAR				0.205 ±.012	94
POLAR BEAR		0.141 ±.003	48	0.132 ±.012	92
WOODCHUCK		0.065 ±.005	92	0.057 ±.005	150
MARMOT	1	0.121 ±.003	96	0.115 ±.007	150
	2	0.090 ±.007	96	0.083 ±.005	158
	3	0.151 ±.012	96	0.130 ±.005	156
	4	0.157 ±.005	82	0.138 ±.009	150
	5	0.174 ±.007	96	0.163 ±.005	150
	6	0.170 ±.008	90	0.160 ±.008	150
	MEAN	0.144 ±.031	92.6 ±5.7	0.132 ±.028	152.3 ±3.6

TABLE 3

QT INTERVALS AND LOW HR's IN TWO SEASONS

SLEEP

		SUMMER QT	HR	WINTER QT
GRIZZLY BEAR	1	0.280 ±.013		0.342 ±.006
	2	0.172 ±.010		0.339 ±.009
MEAN		0.226 ±.057	40±10	0.340 ±.006
BLACK BEAR	1		44	0.340 ±.009
	2		34	0.318 ±.011
MEAN			39±5	0.329 ±.015
POLAR BEAR		0.141 ±.003	48	0.351 ±.024
WOODCHUCK		0.065 ±.005	90	0.034 ±.007
MARMOT	1	0.121 ±.003		0.230 ±.012
	2	0.090 ±.007		0.118 ±.008
	3	0.151 ±.012		
	4	0.157 ±.005		
	5	0.174 ±.007		
	6	0.170 ±.008		
MEAN		0.144 ±.031	90±10	0.174 ±.058

TABLE 4

QT INTERVALS AND HIGH HR's IN TWO SEASONS

		ACTIVE	
	SUMMER		WINTER
	QT	HR	QT
GRIZZLY BEAR 1	0.238 ±.006		0.333 ±.008
2	0.169 ±.011		0.275 ±.009
MEAN	0.204 ±.036	80±4	0.304 ±.031
BLACK BEAR 1		50	0.339 ±.018
2	0.205 ±.012	94	0.217 ±.013
MEAN	0.205 ±.012		0.278 ±.013
POLAR BEAR	0.132 ±.012	92	0.153 ±.013
WOODCHUCK	0.057 ±.005	150	0.078 ±.006
MARMOT 1	0.115 ±.007		0.163 ±.005
2	0.083 ±.005		0.109 ±.007
3	0.130 ±.005		
4	0.138 ±.009		
5	0.163 ±.005		
6	0.160 ±.008		
MEAN	0.132 ±.028	150±10	0.136 ±.029

Fig. 1

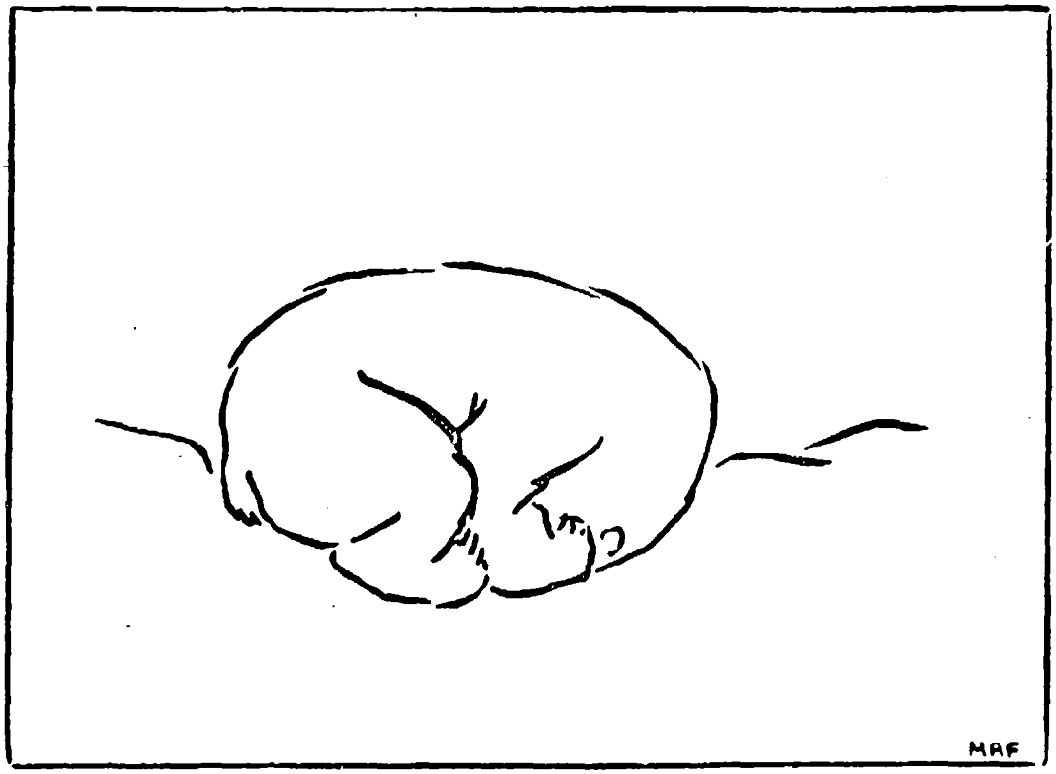


Fig. 2

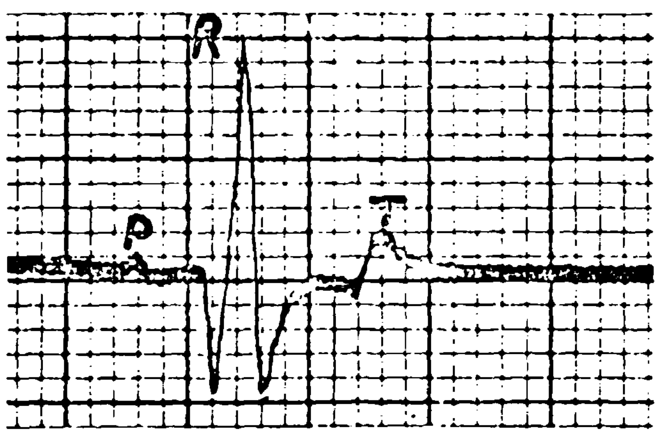
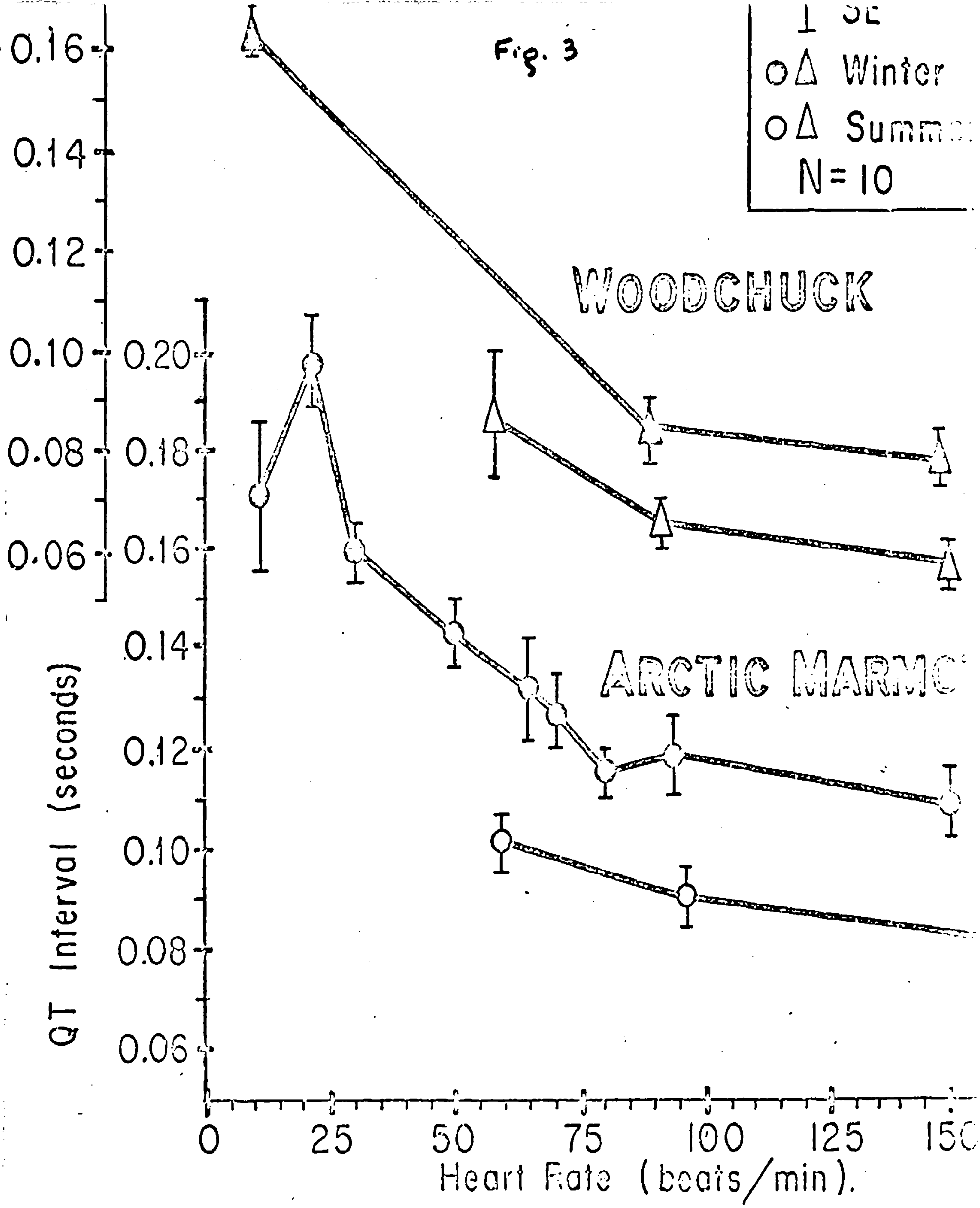


Fig. 3



SE
Winter
Summ
N= 10
WOODCHUCK
ARCTIC MARMO
QT Interval (seconds)
Heart Rate (beats/min).
0.16
0.14
0.12
0.10
0.08
0.06
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0
25
50
75
100
125
150

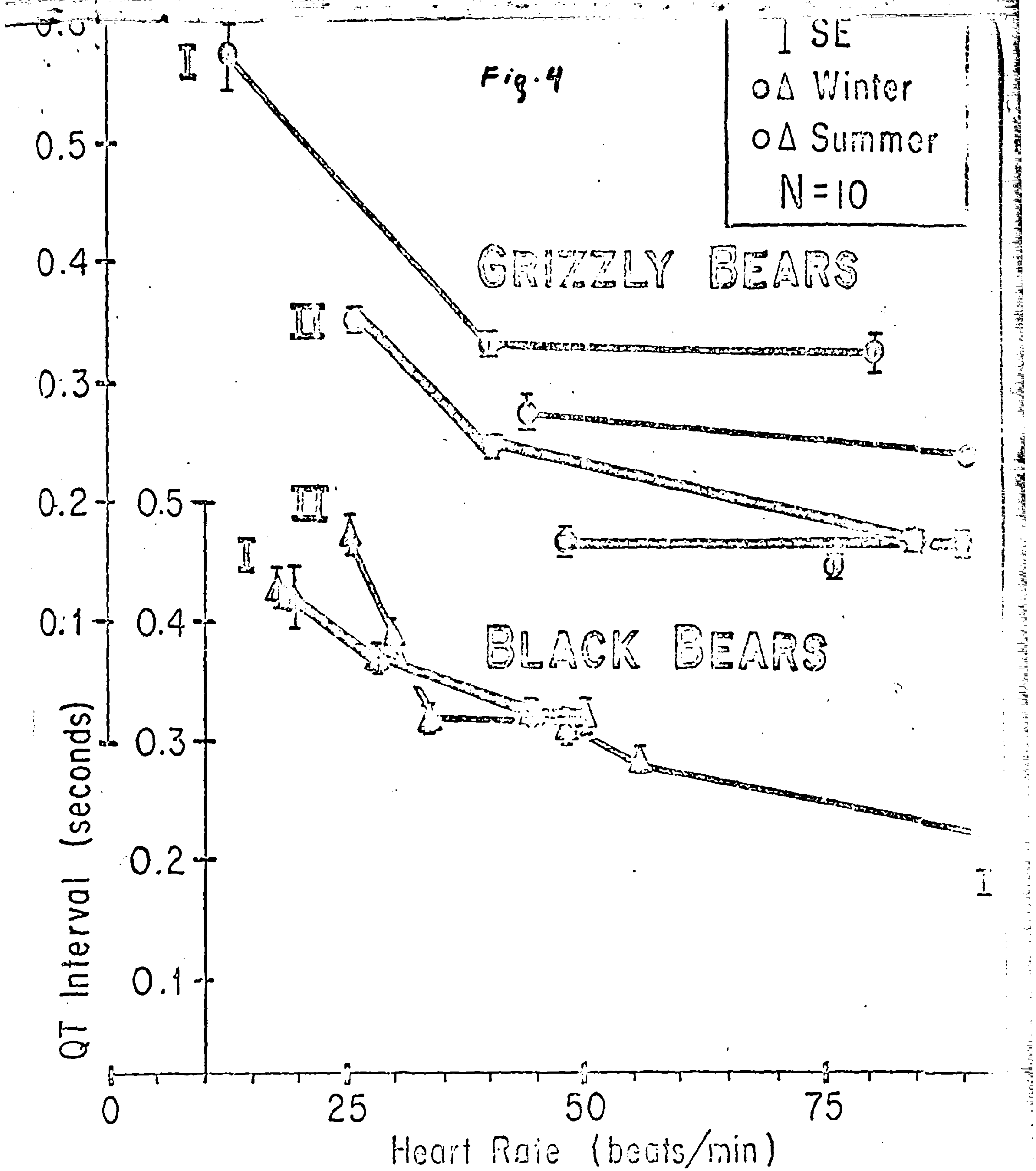


Fig. 4
SE
Winter
Summer
N=10
GRIZZLY BEARS
BLACK BEARS
0.5
0.4
0.3
0.2
0.1
QT Interval (seconds)
0
25
50
75
Heart Rate (beats/min)

Captions to Figures.

Figure 1. Drawing of a hibernating black bear observed intermittently during its dormancy period of several months.

Figure 2. Record of a single heart beat of a polar bear recorded by radio-telemetry. Note the three spikes referred to as P, R, and T.

Figure 3. QT intervals at different heart rates of two marmota-species, in winter and summer. Heart rates lower than 30 b/m represent hibernation.

Figure 4. QT intervals at different heart rates of two species of bears, in winter and summer. Heart rates lower than 40 b/m represent hibernation.